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# Measurement invariance in comparative Internet use research

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## Abstract

Comparative studies in communication and Internet research call for equivalent measures of key constructs that are comparable across populations. This article details and applies the concept of measurement invariance within a cross-nationally comparative context. Multi-group confirmatory factor analysis is used to test configural, metric, and scalar invariance in an empirical example and structural equation modeling introduces exogenous predictors of Internet use types. Results support metric invariance for a four-factor Internet usage model in three English-speaking countries. The significance of measurement invariance testing for unbiased comparative research is discussed.

## 1. Introduction

There have been notable developments in comparative research in the social and behavioral sciences such as psychology and sociology (e.g. Kohn, 1987; Horn & McArdle, 1992; Inglehart & Baker, 2000; Poortinga, Van de Vijver, & Van Hemert, 2002; Berry, Poortinga, Breugelmans, Chasiotis, & Sam, 2011; Davidov, Schmidt, & Billiet, 2011) or political science (e.g. Van Deth, 1998; Boix & Stokes, 2007; Stegmueller, 2011)—but also in media and communication research that specifically analyzes communication processes in social systems (see Esser & Hanitzsch, 2012 for an overview). Comparative communication research deals with diverse questions such as how election campaigning, climate change reporting, or information seeking behavior differ across countries. Comparative Internet use research, in particular, is concerned with cross-country differences in various types of usage, along with their social antecedents and effects. It is likely that the development of user-friendly statistical software combined with the increasing availability of multi-country datasets will lead to a rise in comparative research and the validity of such studies will crucially depend on the cross-national comparability of constructs.

This article exemplifies practical methodological challenges in analyzing Internet usage patterns across multiple countries. If one is interested in the concept of, for example, informational uses of the Internet in country A, a comparison with country B requires the existence of an *equivalent* concept. Since the concept of informational use is not directly observable or measurable but rather a latent construct, operationalizations into manifest variables are necessary: In a survey of Internet users, one of several indicators to measure informational use may be how often the respondent checks facts online. How multiple indicators are then combined needs to be equivalent across populations for meaningful comparisons. However, not only latent constructs can be challenging in comparative research. Even manifest variables such as age may cause problems. The straightforward question "how old are you?" is probably universally comprehensible, but not necessarily interpreted in the same way. As Baron (2010) reports, a Korean and American adult may specify ages two years apart despite having the exact same "actual" age (in Korea, a baby is considered one year old at birth and everyone turns one year older on 1 January). In this case, culturally knowledgeable researchers could simply transform the age variable in their data accordingly to achieve equivalence. For latent constructs with multiple indicators the issue is more complex. In this case, in addition to securing equivalence at the indicator level, the way these single items reflect the underlying latent construct is key (Fontaine, 2005). As Wirth and Kolb (2012) point out, comparative research projects may employ strategies oriented towards avoiding bias ex ante. For example, the questionnaire should avoid ambiguous terms or collaborators in multiple countries should collect data within the same time frame using the same instrument. Due to theoretical interests and practical constraints, many of these strategies may in part prove unfeasible. Once data have been collected, ex post strategies of testing and optimizing equivalence come into play (Davidov, Meuleman, Cieciuch, Schmidt, & Billiet, 2014).

### 1.1. Comparative logic: Countries as context

Comparative communication research contrasts different macro-level units such as countries using different analytical strategies in dealing with the objects of investigation (Esser & Hanitzsch, 2012). In an influential address to the American Sociological Association, Kohn (1987) argued for the usefulness of cross-country research in testing and developing social theory. Based on this, Hasebrink (2012) described four comparative logics: "(1) countries as objects of study; (2) countries as context of study; (3) countries as unit of analysis; and (4) countries as part of a larger international/global system" (p. 384). The second option, country as context, was used in the empirical example below. In this approach, hypotheses regarding correlations between variables of theoretical interest are tested across a sample of countries (Figure 1). The comparative logic of "country as context of study" aims to provide insights into the similarities and differences of the hypothesized relationships and overall model fit for the selected countries. In the Figure 1, V1 and V2 could be sociodemographic attributes (e.g. age and education) that influence the level of a specific type of Internet use (V3; e.g. informational Internet use).

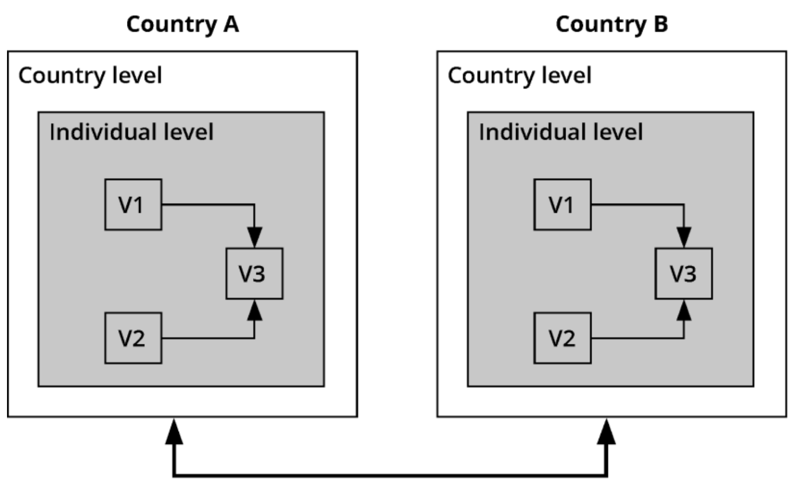


*Figure 1.* Comparative logic of country as a context of study. Source: Modified from Hasebrink (2012, p. 385).

## 1.2. Comparative Internet use research

Ever since the use of the Internet has disseminated outside its academic and military origins, researchers have analyzed the patterns of diffusion and adoption (see e.g. Nie & Erbring, 2000). Internet use as a global phenomenon calls for international and comparative research. While early analyses focused mainly on the United States, there now exist numerous comparative studies of diffusion at the country level (e.g. Andrés, Cuberes, Diouf, & Serebrisky,

2010) and the user level (e.g. Brandtzæg, Heim, & Karahsanovic, 2011). In connection with analyses of diffusion and unequal access, the literature has also assessed differentiated uses across social subgroups revealing further digital divides (e.g. Teo, 2001; Norris, 2001; Van Dijk, 2005; Bonfadelli, 2002; DiMaggio, Hargittai, Celeste, & Shafer, 2004), while current research has shifted to the social outcomes and impacts of Internet use. Amichai-Hamburger and Hayat (2011), for example, conclude from their thirteen-country comparative study that the Internet can enhance the social lives of its users. Van Deursen and Helsper (2015) note that the Internet is more beneficial to those in higher social positions in terms of what they achieve through their use. From the (comparative) literature on Internet use and the digital divide it becomes clear that inequalities in various domains need to be addressed in societies where vital resources for the participation in social life are exclusively or most readily available online (see e.g. Witte & Mannon, 2010; Hargittai, 2008).

Because the Internet is technically merely a network of networks, the applications and uses supported by this infrastructure are extremely broad and diverse. Consequently, several typologies have been suggested for the types and purposes of individual's everyday Internet use. The reduction of the usage dimensionality has frequently been addressed by exploratory as well as confirmatory factor analysis (EFA and CFA). Conceptually a step before actual use, LaRose and Eastin (2004) formulated expected outcomes of use such as finding similar people, finding information, feeling entertained, or finding bargains online. Using EFA and principal component analysis, Blank and Groselj (2014) derived ten usage factors from more than 40 activity variables. Similarly, Van Deursen and Van Dijk (2014) reduced 18 activities to seven usage factors. The theoretical background of such classifications is predominantly based on the uses and gratifications literature developed for traditional media (see Katz, Haas, & Gurevitch, 1973).

Helsper and Gerber (2012) specifically addressed the potential pitfalls of cross-national comparisons of Internet use types. They constructed and tested a measurement model of Internet use comprising communication, information, entertainment, and finance and were able to demonstrate its general applicability in a diverse set of 12 countries (Helsper & Gerber, 2012).

The literature shows that refined measures of Internet use have been developed, yet explicit tests of equivalence remain rare when these are applied in comparative research. Following the comparative logic visualized in Figure 1, the empirical models below deal with individual-level Internet usage differences—within the context of different countries—rather than global comparisons based on macro-level indicators (such as Internet diffusion rates in different countries; see Kiiski & Pohjola, 2002). Aimed at supporting the methodological rigor of future comparative Internet use research, the following sections present the concept of measurement invariance, detail its statistical assessment, and apply the procedures to an empirical example.

## 2. Evaluating measurement invariance in multi-group confirmatory factor analysis and structural equation modeling

### 2.1. Latent variable modeling

This section describes the analytical steps involved in testing cross-country measurement invariance of latent Internet usage types using quantitative survey data in multi-group structural equation modeling (MGSEM). MGSEM expands multi-group confirmatory factor analysis (MGCFA; see Jöreskog, 1971). While MGCFA focuses on measurement models across samples, MGSEM additionally incorporates structural modeling. In CFA, an individual's observable response ($x_i$) to an item (i) is considered to be made up of an intercept ($\tau_i$), a slope ($\lambda_{ij}$) of the regression of $x_i$ on a latent construct ($\xi_j$), and a stochastic error term ($\delta_i$) (Steenkamp & Baumgartner, 1998; Brown, 2015). Each item score is essentially treated like an outcome variable in a simple regression model of the type $y_i=\alpha+\beta xi+\varepsilon_i$:

$$x_i = \tau_i + \lambda_{ij}\xi_j + \delta_i$$

For reflective measurement models it is important to note the implied causal flow: The latent construct is responsible for the answers in the manifest indicator items—it is not the items that form the latent construct (see Edwards, 2011). For example, people who are very conscientious would likely agree with the item “I pay attention to details.” Here, conscientiousness as a latent personality trait (see Costa & McCrae, 1992) causes individuals to produce certain scores on the manifest items; the item reflects—albeit imperfectly—the underlying factor. In this view, measurement items are interchangeable, meaning that omission or inclusion of a different *valid* indicator would not substantially alter the meaning of the latent factor (Brown, 2015). Empirical correlations among indicators are due to their common cause, the latent construct. In contrast, non-observable composite variables such as socioeconomic status (SES) depend on all of their formative indicators. Education, income, and occupational prestige cause rather than reflect SES.

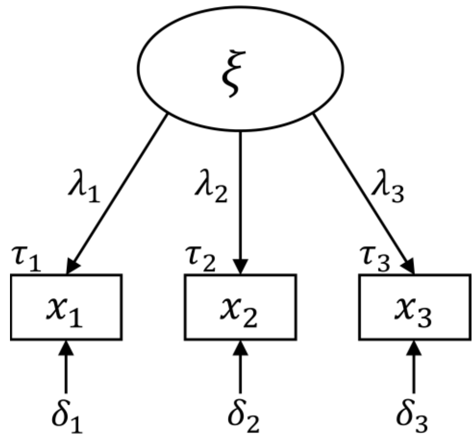


*Figure 2.* A latent factor ($\xi$) with three indicator items ($x_1$, $x_2$, $x_3$) that can be tested in multiple groups (countries). ($\xi$, latent factor; $\lambda$, factor loading; $\tau$, item intercept; x, indicator item; $\delta$, measurement error)

## 2.2. Model fit

In structural equation modeling (SEM), a first indication of the fit between the empirical data (i.e., the observed covariance matrix) and the model-implied structure is the $\chi^2$ test—a small value and an insignificant result indicate that the empirical and hypothesized relationships do not differ statistically (Brown, 2015). Besides parsimony adjustment of the $\chi^2$ value with the degrees of freedom (df), other criteria for model evaluation are commonly used in CFA and SEM (see Bentler, 1990; Schermelleh-Engel, Moosbrugger, Müller, 2003; Kline, 2011). The goodness-of-fit measures used here are the comparative fit index (CFI), the non-normed fit index (NNFI) also known as the Tucker–Lewis index (TLI), the root mean square error of approximation (RMSEA), an estimate of the probability that the RMSEA is ≤.05 in the population (PCLOSE), and the standardized root mean square residual (SRMR). The literature on CFA and SEM suggests various cutoff criteria that help guide applied research in deciding which models should to be rejected and which may be retained (see e.g. Hu & Bentler, 1999; Schermelleh-Engel et al., 2003; Brown, 2015; Chen, 2007; Byrne, 2010; Kline, 2011). Models with $\chi^2$/df ≤ 3, CFI ≥ .95, TLI ≥ .95, RMSEA ≤ .08, and SRMR ≤ .10 are generally considered to have an acceptable fit.

With large sample sizes, the $\chi^2$ test is very likely to be significant even if approximate fit indexes such as CFI and RMSEA indicate a good fit (Kline, 2011). An acceptable or good overall model fit is key in SEM and MGSEM—only then does it make sense to interpret the coefficients of interest.

### 2.3. Measurement invariance as a precondition for cross-country comparisons

For valid cross-country comparisons, the concepts of interest need to be comparable, i.e. invariant or equivalent, across countries. Measurement invariance within a CFA framework can be statistically tested on increasingly restrictive levels in nested models (see Schermelleh-Engel et al., 2003; Billiet, 2003). The most commonly used hierarchy employs three levels of measurement invariance: configural, metric, and scalar (Steenkamp & Baumgartner, 1998; Davidov et al., 2014). These three levels have also been recently applied in various subdisciplines of communication research (see Wirth & Kolb, 2012; Helsper & Gerber, 2012; Kühne, 2013; Odag, Hofer, Schneider, & Knop, 2016; for an overview see Vandenberg and Lance, 2000). Many statistical software programs provide extensive functionalities for testing different levels of measurement invariance (for IBM SPSS Amos, see Byrne, 2004 and Arbuckle, 2012; for R/lavaan, see Rosseel, 2012; for MPlus, see Muthén & Muthén, 2015). While Amos offers a graphical point-and-click interface to draw and test models, R and MPlus are largely syntax based.

The least restrictive level, *configural* invariance, requires that the proposed model fits all groups, in this case countries, meaning that aside from overall model fit, all items load significantly and substantially on the intended factor for every country. Standardized item loadings above 0.3 can be considered substantial (Brown, 2015, p. 27). This means that after being freely estimated, each factor's specified items have a loading significantly different from zero in each country; loadings that were not specified in the model are implicitly fixed to zero (and therefore also implied to be equal across countries). If the overall pattern of these salient and non-salient loadings is observable for every country sample, the constructs are similarly interpreted in each population. Evidence of configural invariance combined with an acceptable model fit in every country allows the exploration of the basic structure of the construct cross-nationally (Steenkamp and Baumgartner, 1998, p. 83).

For a simple two-country (A and B) metric invariance test of the exemplary single-factor measurement model in Figure 2, only the factor loading of one item is constrained to unity in both countries, for example:

$$\lambda_{1A} = \lambda_{1B} = 1$$

In this example, $x_1$ is the reference item and therefore its unstandardized factor loading ($\lambda_1$) is fixed to one in both countries to scale the latent factor and to allow for model identification. The configural model indicates absence of construct bias and serves as a baseline against which further models can be tested (Vandenberg & Lance, 2000; Van de Vijver & Tanzer, 2004). Without configural invariance, it would not even make sense to discuss the latent construct for every country (Davidov et al., 2014).

*Metric* invariance is achieved if additionally constraining the factor loadings of the measurement items to be equal across countries does not result in a substantial decrease in model fit. Metric invariance means that the factor loadings do not differ significantly across countries and that an increase of one unit on the item scale has the same meaning in countries A and B. Where the conditions of metric invariance are satisfied, the structural relationships between variables may be examined (Steenkamp & Baumgartner, 1998). This is crucial for many research interests concerned with correlations between constructs—how one factor influences (directed) or covaries with (undirected) another factor can only be meaningfully compared if the factors have invariant loadings, and thus mean the same in the different countries (Kline, 2011, p. 253).

Imposing equality constraints on a model increases the degrees of freedom; more parameters are fixed and accordingly fewer parameters need to be estimated. However, the constraints typically also increase the discrepancy between the empirical and the model-implied covariance matrix ($\chi^2$) because strict equality of factor loadings across multiple countries is highly unlikely. A significant $\chi^2$-difference test between an unconstrained and a model with constrained factor loadings does therefore not necessarily mean that metric invariance is unsupported. Commonly, the change in CFI (ΔCFI) is used to judge whether or not model fit has substantially decreased (Chen, 2007; Cheung & Rensvold, 2002). If the more constrained model has an acceptable fit and the decrease in model fit compared to the less constrained model is minor (ΔCFI ≤ .01, see Byrne, 2010; Cheung & Rensvold, 2002), invariance may be assumed. Building on the configural invariance model above, equality constraints for the remaining factor loadings are *added*. The metric invariance constraints are specified as:

$$\lambda_{1A} = \lambda_{1B} = 1$$

$$\lambda_{2A} = \lambda_{2B}$$

$$\lambda_{3A} = \lambda_{3B}$$

In CFA and SEM, latent factor means can be estimated (see Steinmetz, 2011). In order to statistically compare these means across countries, the item intercepts in addition to the loadings need to be equivalent. This level is called *scalar* invariance; it is not a necessity for research questions concerned with the structural relationships between factors (i.e. effects and covariances). However, if the interest lies in comparing the means of factor scores across countries, scalar invariance needs to be supported. In addition to constructs carrying the same meaning, scalar invariance indicates that item scores are not systematically biased across countries (Steenkamp & Baumgartner, 1998). Accordingly, respondents from different countries with the same value on the latent factor have the same expected score on the measurement item (Davidov et al., 2014, p. 64). For the scalar invariance model, equality constraints for the item intercepts are added to the ones above, resulting in:

$$\lambda_{1A} = \lambda_{1B} = 1$$

$$\lambda_{2A} = \lambda_{2B}$$

$$\lambda_{3A} = \lambda_{3B}$$

$$\tau_{1A} = \tau_{1B}$$

$$\tau_{2A} = \tau_{2B}$$

$$\tau_{3A} = \tau_{3B}$$

When the required invariance level is supported, pairwise parameter comparisons can be interpreted. Suppose one is interested in the effect of a latent exogenous factor $\xi_1$ on a latent endogenous factor $\xi_2$ in countries A and B and metric measurement invariance has been established. A simple regression of $\xi_2$ on $\xi_1$ estimates the effect for both countries (for an example, see Kühne, 2013). In Amos, a critical ratio (CR) for the absolute difference between the two estimates in countries A and B divided by an estimate of the standard error of this difference is reported. The CR can then be compared to z-values from the standard normal distribution: An effect difference is significant at the .001 level if CR ≥ 3.291. The cutoffs for the widely-used .01 and .05 levels are 2.576 and 1.960, respectively.

### 2.4. Non-invariance and partial measurement invariance

When the data do not support measurement invariance, comparisons between countries are not meaningful and the interpretation of differences is difficult (see Chen, 2008). Depending on the research goals, different strategies may be employed (see Davidov et al., 2014). For example, with a larger set of countries, subgroups can be tested and non-invariant countries can be dropped from further analyses. On the other hand, if all countries are crucial for the research question, a subset of invariant constructs could be used. If, however, a study examines the relationship between two latent factors in two countries, neither of the above steps would be sensible. Another alternative then, is to modify the measurement model by dropping non-invariant items or by establishing partial metric or partial scalar invariance—at least one item other than the reference item for each factor needs to be invariant (see Steenkamp & Baumgartner, 1998; Byrne, Shavelson, & Muthén, 1989). An appropriate strategy in dealing with non-invariance should therefore consider the potential impact on substantive conclusions and balance the number of countries, constructs, and indicators in order to minimize the loss of valuable information.

### 2.1. A note on possible causes of non-equivalence

Having established measurement invariance, the researcher can be confident that the constructs under study are equivalent, meaning that empirical differences between countries are unbiased. Assuming the possibility of equivalence in the first place, however, implies an etic position that may obscure group-specific phenomena (see e.g. Davidson, Jaccard, Triandis, Morales, & Diaz-Guerrero, 1976) because the meaning of some concepts is different across cultures or does not exist (e.g. the political left–right continuum, see Piurko, Schwartz, & Davidov, 2011; Wirth & Kolb, 2004). Therefore, the absence of *construct bias* needs to be supported by both theoretical considerations and configural invariance. *Method bias* can follow from differences in sampling procedures or survey administration across countries (Wirth & Kolb, 2012), as well as variation in the response styles of different groups (e.g. social desirability, Phillips & Clancy, 1972). *Item bias* occurs when the indicators of the latent constructs are poorly translated or include terms that are interpreted differently across countries. Non-equivalence can be addressed statistically by means of measurement invariance tests as detailed above, but others measures of securing equivalence need to be implemented during study development, questionnaire design, and data collection (see Davidov et al., 2014, Wirth & Kolb, 2012).

## 3. An empirical example: Predicting Internet usage types across five countries

### 3.1. Data and method

We used 2012 and 2013 data from the World Internet Project (WIP) to apply the methodological and statistical procedures detailed above. For more details on the theory of the digital divide and the substantive results of these analyses, please refer to Büchi, Just, and Latzer (2015). The WIP joins more than 30 countries to investigate the social, political, and economic impact of information and communication technologies (Cole, Suman, Schramm, Zhou, & Reyes-Sepulveda, 2013; Cardoso, Liang, & Lapa, 2013). For this investigation of Internet uses, five countries with high Internet access rates were selected where the Internet can be considered an integral part of everyday life: New Zealand (NZ) (Gibson, Miller, Smith, Bell, & Crothers, 2013), Sweden (SE) (Findahl, 2013), United States (US) (Cole, Suman, Schramm, Zhou, & Salvador, 2013), Switzerland (CH) (Latzer, Just, Metreveli, & Saurwein, 2013; Just, Latzer, Metreveli, & Saurwein, 2013), and United Kingdom (UK) (Dutton & Blank, 2013). Telephone, web, and face-to-face interviews were conducted with users and non-users of the Internet aged 16 years and older. For our analyses of Internet uses, non-users were excluded, resulting in sample sizes of 1849 for NZ, 2506 for SE, 1123 for the US, 928 for CH, and 1590 for the UK.

The mean age in the combined sample (N=7996) was 44.3 years (SD=17.15). Women (49.95%) and men (50.05%) were equally represented.

Based on previous literature (Nie & Erbring, 2000; Flanagin & Metzger, 2001; LaRose & Eastin, 2004; Helsper & Gerber, 2012) and the conceptual typology of Internet activities used in the WIP, a measurement model for four types of Internet use was developed: social interaction, information seeking, entertainment, and commercial transaction. Several activity items were assigned to each of the four factors (Table 1). For example, listening to or downloading music online was considered an indicator of a respondent's use of the Internet for entertainment purposes (see Büchi et al., 2015). It was hypothesized that the four factors are positively related—users who score high on one usage type tend to also use the Internet intensively for other purposes. These types of Internet use (factors) were then predicted by two correlated exogenous manifest variables (age and years of Internet experience) to reveal social differences in usage (i.e. second-level digital divides). All models were tested using IBM SPSS Amos with maximum likelihood estimation.

Table 1

*Measurement Items for the Four Latent Internet Usage Types.*

| Usage type | Item | Wording |
|---|---|---|
| Social interaction (SOCINT) | instmes | *do instant messaging* |
| | postpics | *post photos or pictures on the Internet* |
| | sns* | *visit social networking or video-sharing websites* |
| Information seeking (INFORM) | deflook | *look up a definition of a word* |
| | factcheck* | *find or check a fact* |
| Entertainment (ENTERT) | music* | *download or listen to music* |
| | video | *download or watch videos* |
| Commercial transaction (COMMTR) | travres | *make travel reservations/bookings* |
| | netbill | *pay bills* |
| | netpur* | *buy things online* |

*Note*: Survey question: "How often do you use the Internet for the following purposes? On average, how frequently do you…?" All items were measured on a 6-point frequency scale: several times a day, daily, weekly, monthly, less than monthly, or never.

* The latent variable was scaled to this reference item by constraining its unstandardized factor loading to unity.

### 3.1. Results

The first step involved testing the same four-factor measurement model with every country's empirical covariance matrix separately (Table 2, single country models). This produced good fit statistics in NZ, the UK, and the US (although it must be noted that all models produced significant $\chi^2$ values typical for large sample sizes). Overall, the measurement model fit the data best in the US. For SE and CH, the goodness-of-fit measures could be argued to be acceptable. However, the TLI was below the suggested cutoff of .95 for both countries. A model including all five countries as groups still showed a good overall fit (Table 2, models 1 to 5). Since the single-country models for SE and CH showed some lack of fit and because further invariance testing could unsurprisingly not support metric invariance, subsequent analyses focused on NZ, the UK, and the US. A three-country configural invariance model (no constraints except fixing reference items to 1) also fit the data very well (Table 2, model 7). Constraining corresponding factor loadings to be equal across these three countries produced the metric invariance model which exhibited a good overall fit (Table 2, model 8). The increase in $\chi^2$ as compared to the unconstrained model was significant, but the very minor decrease in CFI ($\Delta$CFI=.004) nonetheless indicates full metric invariance of the four-factor Internet usage model across NZ, the UK, and the US. The evidence of metric variance made it possible to use these measures of Internet use types in a structural model that introduced exogenous predictors. Imposing equality constraints on the item intercepts heavily influenced the model fit: the CFI dropped from .979 to .777 (Table 2, model 9). Therefore, scalar measurement invariance could not be established, meaning that cross-country comparisons of latent factor means would be biased.

Table 2

*Model Comparison: Single Countries, Invariance Levels, and Model Fit Change.*

| Nr. | Model description | Compared model | n | $\chi^2$ (p) | df | CFI | RMSEA (PCLOSE) | TLI | SRMR | ΔCFI | $\Delta\chi^2$ | Δdf | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Single country NZ | | 1849 | 106.49 (<.001) | 29 | .984 | .038 (.994)) | .976 | .027 | - | - | - | - |
| 2 | Single country UK | | 1590 | 151.67 (<.001) | 29 | .978 | .052 (.358) | .966 | .032 | - | - | - | - |
| 3 | Single country US | | 1123 | 73.42 (<.001) | 29 | .988 | .037 (.980) | .981 | .028 | - | - | - | - |
| 4 | Single country SE | | 2506 | 307.92 (<.001) | 29 | .951 | .062 (.001) | .923 | .044 | - | - | - | - |
| 5 | Single country CH | | 928 | 104.24 (<.001) | 29 | .963 | .053 (.314) | .942 | .043 | - | - | - | - |
| 6 | Configural (NZ, UK, US, SE, CH) | | 7996 | 743.72 (<.001) | 145 | .973 | .023 (1.00) | .957 | .027 | - | - | - | - |
| 7 | Configural (NZ, UK, US) | | 4562 | 331.57 (<.001) | 87 | .983 | .025 (1.00) | .973 | .027 | - | - | - | - |
| 8 | Metric (NZ, UK, US) | 7 | 4562 | 401.36 (<.001) | 99 | .979 | .026 (1.00) | .971 | .031 | .004 | 69.79 | 12 | <.001 |
| 9 | Scalar (NZ, UK, US) | 8 | 4562 | 3268.24 (<.001) | 111 | .777 | .079 (.000) | .729 | .038 | .202 | 2866.88 | 12 | <.001 |
| 10 | Structural (NZ, UK, US) | | 4562 | 653.59 (<.001) | 123 | .969 | .030 (1.00) | .951 | .037 | - | - | - | - |

Based on the three-country measurement model (NZ, UK, US) we then proceeded to build a structural model. After having demonstrated metric invariance, the constraints on the factor loadings were released and two correlated exogenous variables, age and internet experience, were introduced as predictors of the usage types (Figure 3). This structural model also fit the data well (Table 2, model 10). The parameter estimates for the effects of age and Internet experience are shown in Table 3 (Appendix).

Age has significant effects on all four usage types in all three countries. Particularly social interaction use and entertainment use are strongly dependent on age with regression weights ranging from -.52 to -.69. Younger Internet users show much higher levels on these factors, which is consistent with the literature. Given metric invariance, these age effects may be directly compared across countries. The largest critical ratio resulting from pairwise parameter comparisons (Table 4, Appendix) point to significant differences in the way age influences informational use of the Internet in the US and the UK. Older adults in the US use the Internet much less for information seeking purposes than younger users while this effect is small in the UK ($\beta_{US}$=-.44, p<.001; $\beta_{UK}$=-.19, p<.001; CR=6.604).

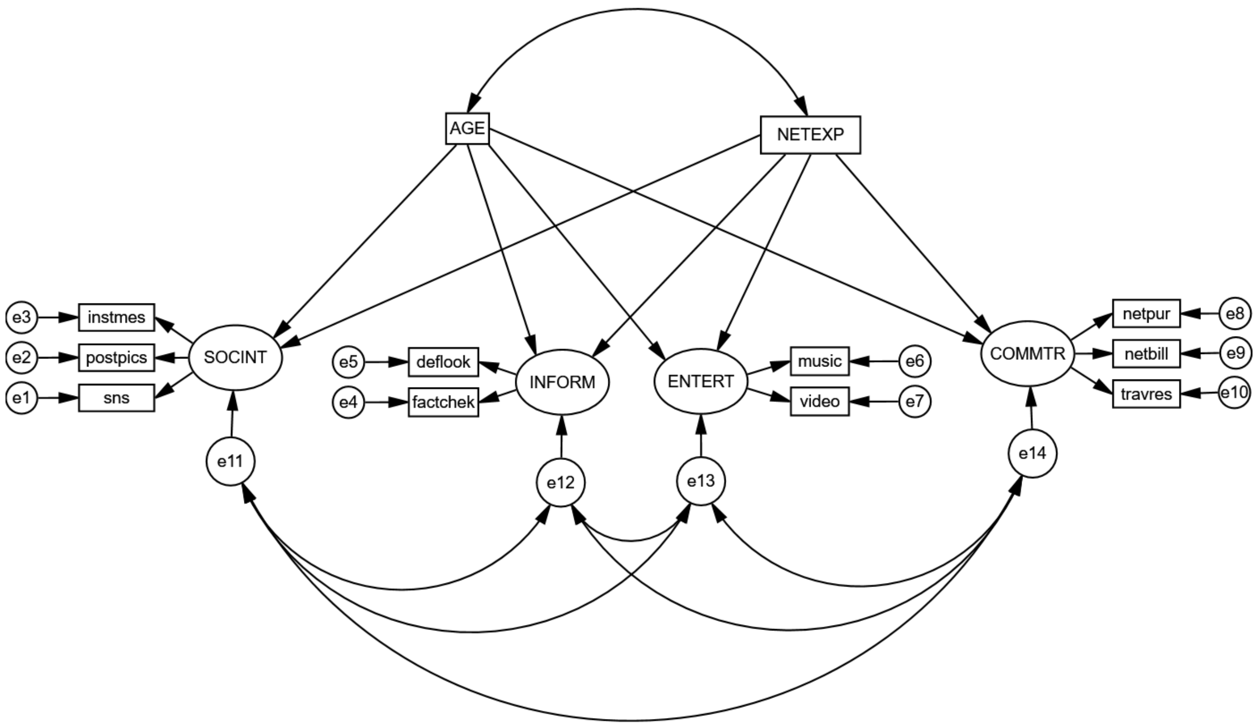


*Figure 3.* Structural model: Two exogenous manifest variables predict the four latent Internet usage types. See Table 3 in the appendix for parameter estimates.

The number of years a respondent has been using the Internet (NETEXP) also showed mostly significant effects on the usage types, most notably on commercial transaction usage and to a lesser extent on informational usage (Table 3, Appendix). Experienced users engage more frequently in commercial and informational activities such as buying products or checking facts online. Again, these effects were present in all three countries but differed in their magnitude (although differences were less pronounced than in the case of age). For example, in the US, informational use depends more strongly on Internet experience than in the UK ($\beta_{US}$=.27, p<.001; $\beta_{UK}$=.12, p<.001; CR=3.705).

The inclusion of age and Internet experience highlighted another interesting effect. These two variables are positively correlated in NZ and in the US but not in the UK. The positive association indicates that only users of a certain age have the possibility of having been online for a number of years. As shown above, more experienced users are those who use the Internet more frequently for all four types. On the other hand, the age effect is even stronger—younger users are much more frequent users of all four types.

## 4. Discussion and conclusion

Using invariance testing in MGFCA, this article was able to build a model with invariant Internet usage types that allowed the cross-national comparison of structural relationships. Nonetheless, many theoretical and methodological challenges in cross-country research remain (see e.g. Hoffmeyer-Zlotnik & Harkness, 2005; Levine, Park, & Kim, 2007; Church, 2010). Even research projects that are designed with a comparative goal from the outset such as the WIP (see Cardoso et al., 2013) do not guarantee equivalence. Using countries as context of study (Figure 1), was not without disadvantages. Many variables are of course not accounted for, meaning that even though the countries used are similar with regards to internet diffusion, they naturally differ drastically in other dimensions. Particularly in interpreting results, it would thus be valuable to collaborate with researchers from the respective countries not only for the data collection stage but also in the analysis in order to include local knowledge (see Hasebrink, Olaffson, & Stetka, 2010). Measurement invariance tests showed that the internet activity items relate to the corresponding factors in the same way only for UK, US, and NZ. Consistent with Odag et al. (2016), we found evidence of invariance despite differences in the way the questionnaire was administered. The effects of common language appear to be strongest, as the

English-speaking NZ, UK, and US showed invariant factor loadings. This can in part be explained by the fact that the Internet has historically been—and to a large part, still is—dominated by the English language (see Warschauer, 2003). Related to the issue of language, another explanation may be found in the connections between traditional media use such as television and Internet use. The invariant countries might share certain cultural aspects (see Straubhaar, 1991; Hofstede, 2001) that explain similarities in the way usage types like entertainment are reflected in concrete activities. A competing hypothesis to cultural proximity, geographical proximity, was not supported since the European countries UK, CH, and SE were not invariant regarding the factor loadings in the Internet use measurement model (also see Helsper & Gerber, 2012).

The goal of this article was to raise awareness for the importance of equivalence, particularly in light of increasing comparative Internet research. For valid comparisons of the relationships between Internet usage types, metric invariance should be supported. In order to compare the levels of use across populations (i.e. mean comparisons), scalar invariance is required. The concept and practical steps of measurement invariance testing described in this article thus demonstrate one useful component in broader strategies aimed at rigorous comparative research.

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# Appendix

Table 3

*Parameter Estimates for Different Models*

| | Single country models | | | | | Metric model | | | Structural model | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NZ | UK | US | SE | CH | NZ | UK | US | NZ | UK | US |
| Factor loadings (upper rows: standardized estimates; lower rows: unstandardized estimates). | | | | | | | | | | | |
| instmes | .68 | .69 | .52 | .53 | .61 | .65 | .69 | .58 | .68 | .71 | .51 |
| | 1.02*** | .86*** | .69*** | .66*** | .85*** | .89*** | .89*** | .89*** | .97*** | .88*** | .68*** |
| postpics | .78 | .77 | .72 | .48 | .58 | .77 | .79 | .72 | .75 | .76 | .72 |
| | .84*** | .70*** | .70*** | .41*** | .56*** | .76*** | .76*** | .76*** | .78*** | .70*** | .69*** |
| sns | .69 | .81 | .68 | .70 | .64 | .73 | .79 | .64 | .72 | .80 | .69 |
| | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| deflook | .80 | .84 | .81 | .70 | .65 | .78 | .82 | .84 | .79 | .83 | .81 |
| | 1.08*** | 1.05*** | .91*** | .92*** | .73*** | 1.00*** | 1.00*** | 1.00*** | 1.05*** | 1.03*** | 0.90*** |
| factcheck | .79 | .82 | .88 | .73 | .82 | .81 | .84 | .86 | .80 | .83 | .89 |
| | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| video | .72 | .77 | .77 | .71 | .77 | .68 | .80 | .76 | .74 | .76 | .76 |
| | 1.04*** | .82*** | .97*** | .77*** | .98*** | .92*** | .92*** | .92*** | 1.09*** | .78*** | .94*** |
| music | .72 | .80 | .79 | .77 | .70 | .76 | .76 | .80 | .71 | .81 | .80 |
| | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| travres | .58 | .71 | .64 | .50 | .61 | .61 | .67 | .66 | .55 | .70 | .63 |
| | .69*** | .84*** | .73*** | .55*** | .68*** | .76*** | .76*** | .76*** | .67*** | .83*** | .73*** |
| netbill | .57 | .63 | .62 | .39 | .51 | .56 | .66 | .59 | .60 | .65 | .64 |
| | 1.02*** | .98*** | 1.08*** | .51*** | .81*** | 1.02*** | 1.02*** | 1.02*** | 1.09*** | 1.01*** | 1.14*** |
| netpur | .70 | .70 | .71 | .82 | .73 | .69 | .72 | .71 | .70 | .70 | .70 |
| | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Covariances (upper rows: standardized estimates; lower rows: unstandardized estimates). | | | | | | | | | | | |
| SOCINT <--> INFORM | .48 | 41 | .61 | .71 | .23 | .47 | .41 | .62 | .34 | .38 | .51 |
| | .58*** | .66*** | 1.00*** | .87*** | .36*** | .64*** | .66*** | .88*** | .32*** | .48*** | .64*** |
| SOCINT <--> ENTERT | .67 | .74 | .79 | .76 | .65 | .67 | .74 | .79 | .45 | .60 | .70 |
| | .92*** | 1.32*** | 1.34*** | 1.21*** | .86*** | 1.04*** | 1.19*** | 1.26*** | .37*** | .71*** | .81*** |
| SOCINT <--> COMMTR | .47 | .36 | .44 | .55 | .32 | .47 | .37 | .44 | .43 | .40 | .42 |
| | .40*** | .36*** | .40*** | .47*** | .29*** | .42*** | .36*** | .37*** | .27*** | .30*** | .31*** |
| INFORM <--> ENTERT | 0.56 | 0.48 | 0.7 | 0.65 | 0.64 | 0.55 | 0.48 | 0.70 | 0.46 | 0.46 | 0.62 |
| | .62*** | .63*** | 1.10*** | .81*** | .86*** | .67*** | .61*** | 1.08*** | .34*** | .49*** | .68*** |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| INFORM <--> COMMTR | .49 | .49 | .51 | .65 | .54 | .49 | .49 | .50 | .40 | .47 | .45 |
| | .34*** | .35*** | .43*** | .43*** | .50*** | .34*** | .37*** | .41*** | .23*** | .32*** | .31*** |
| ENTERT <--> COMMTR | .42 | .38 | .36 | .48 | .50 | .42 | .38 | .36 | .37 | .39 | .35 |
| | .32*** | .31*** | .32*** | .42*** | .40*** | .33*** | .29*** | .33*** | .18*** | .25*** | .22*** |
| age <--> netexp | - | - | - | - | - | - | - | - | .22 | .04 | .16 |
| | - | - | - | - | - | - | - | - | 20.57*** | 3.01 (.151) | 16.05*** |
| Structural regressions (upper rows: standardized estimates; lower rows: unstandardized estimates). | | | | | | | | | | | |
| age --> SOCINT | - | - | - | - | - | - | - | - | -.62 | -.59 | -.52 |
| | - | - | - | - | - | - | - | - | -.05*** | -.05*** | -.04*** |
| age --> INFORM | - | - | - | - | - | - | - | - | -.39 | -.19 | -.44 |
| | - | - | - | - | - | - | - | - | -.02*** | -.01*** | -.03*** |
| age --> ENTERT | - | - | - | - | - | - | - | - | -.69 | -.59 | -.64 |
| | - | - | - | - | - | - | - | - | -.04*** | -.04*** | -.05*** |
| age --> COMMTR | - | - | - | - | - | - | - | - | -.28 | -.10 | -.18 |
| | - | - | - | - | - | - | - | - | -.01*** | -.00*** | -.01*** |
| netexp --> SOCINT | - | - | - | - | - | - | - | - | .12 | .00 | .11 |
| | - | - | - | - | - | - | - | - | 0.03*** | 0.00 (.939) | 0.03** |
| netexp --> INFORM | - | - | - | - | - | - | - | - | .24 | .12 | .27 |
| | - | - | - | - | - | - | - | - | .05*** | .03*** | .06*** |
| netexp --> ENTERT | - | - | - | - | - | - | - | - | .09 | .07 | .09 |
| | - | - | - | - | - | - | - | - | .02*** | .02** | .02** |
| netexp --> COMMTR | - | - | - | - | - | - | - | - | .38 | .28 | .33 |
| | - | - | - | - | - | - | - | - | .05*** | .04*** | .04*** |

* p<.05
** p<.01
*** p<.001

Table 4

*Critical Ratios (CR) for Pairwise Parameter Comparisons*

| | NZ vs. UK | NZ vs. US | UK vs. US |
|---|---|---|---|
| age <--> netexp | 5.798 | 1.209 | 3.53 |
| age --> SOCINT | 2.224 | 1.674 | 3.461 |
| age --> INFORM | 4.237 | 3.175 | 6.604 |
| age --> ENTERT | 0.084 | 1.303 | 1.339 |
| age --> COMMTR | 4.439 | 2.406 | 1.612 |
| netexp --> SOCINT | 3.156 | 0.382 | 2.378 |
| netexp --> INFORM | 2.525 | 1.604 | 3.705 |
| netexp --> ENTERT | 0.032 | 0.369 | 0.369 |
| netexp --> COMMTR | 2.18 | 1.611 | 0.446 |